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On the accuracy of HITEMP-2010 calculated emissivities of water vapor and carbon dioxide

**12th International Conference on Energy for a Clean
Environment**

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5 – 9 July, 2015



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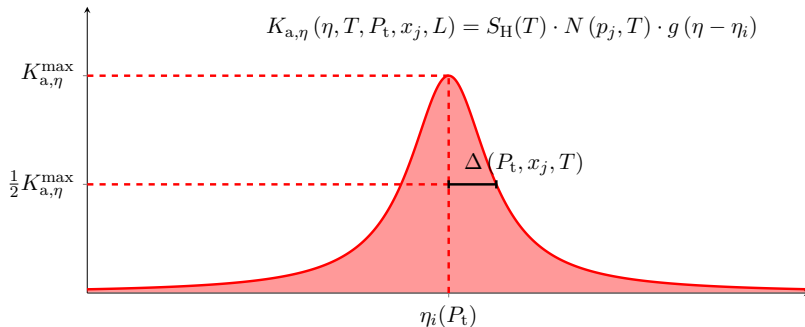
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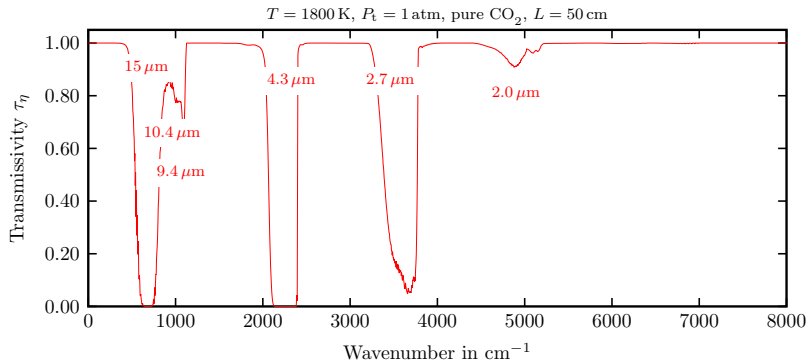
Summary and Conclusion

Line-by-Line Method



- 7 Parameter for each line are needed from Spectral database
- Equation of state: Ideal gas law
- Lineshape: Lorentz
- $a_\eta = \sum_{\text{all lines}} K_{a,\eta}$

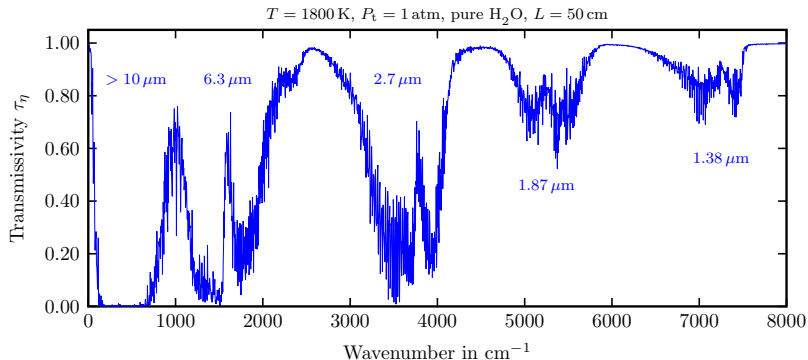
Line-by-Line Method



$$\tau_\eta = \exp(-a_\eta \cdot L)$$

$$\varepsilon_\eta = 1 - \tau_\eta$$

Line-by-Line Method



$$\varepsilon^{\text{tot}} = \frac{1}{\sigma \cdot T^4} \cdot \int_0^\infty \varepsilon_\eta \cdot \frac{c_1 \cdot \eta^3}{\exp\left(\frac{c_2 \cdot \eta}{T}\right) - 1} \cdot d\eta$$



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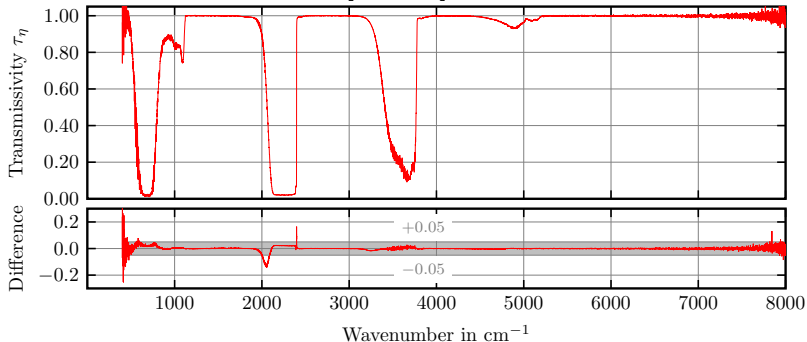
High Temperature

Important Measurements (without any claim to completeness)

- Modest & Bharadwaj (2002-2007) [5, 6, 11]
 - up to 1550 K, CDSD-1000 and HITEMP-1995, 4 cm^{-1}
 - also compared with HITEMP-2010, see Alberti et. al. [1]
- Becher et. al. (2012) [4]
 - up to 1770 K, HITEMP-2010, Measurements performed at DTU, 32 cm^{-1}
- Alberti et. al. (2015) [3]
 - 22 cases, 500 - 1770 K, also mixtures, DTU, 1 cm^{-1}
 - whole spectral range from 450 to 7600 cm^{-1}

High Temperature - Alberti et. al. (2015)

CO_2 at 1770 K, $x_{\text{CO}_2} = 0.43$, $x_{\text{N}_2} = 0.57$, $P_t = 1 \text{ atm}$, $L = 54 \text{ cm}$

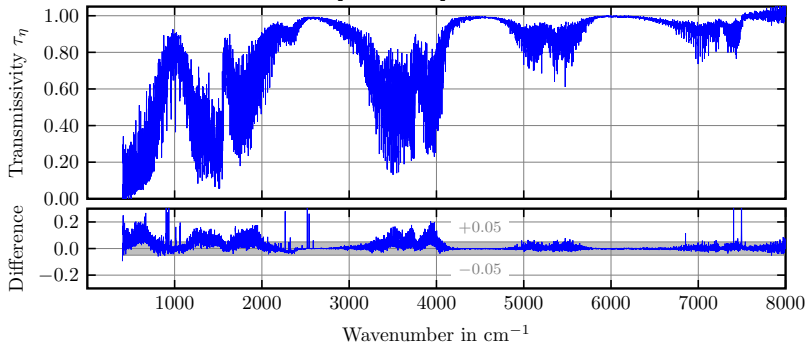


$$\text{Difference} = \tau_{\eta, \text{Measured}} - \tau_{\eta, \text{HITEMP-2010}}$$

see Alberti et. al. [3]

High Temperature - Alberti et. al. (2015)

H_2O at 1770 K, $x_{\text{H}_2\text{O}} = 0.43$, $x_{\text{N}_2} = 0.57$, $P_t = 1 \text{ atm}$, $L = 54 \text{ cm}$

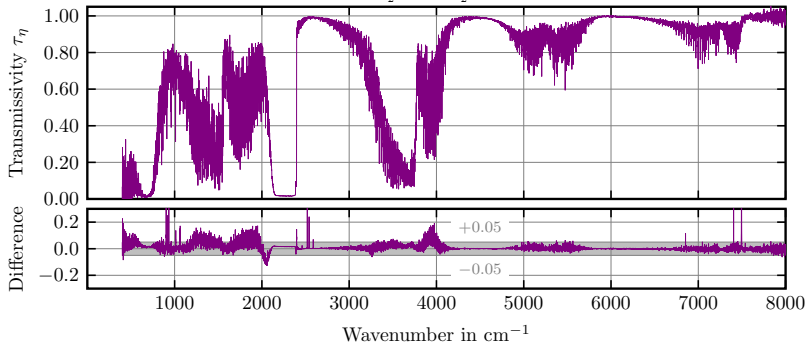


$$\text{Difference} = \tau_{\eta, \text{Measured}} - \tau_{\eta, \text{HITEMP-2010}}$$

see Alberti et. al. [3]

High Temperature - Alberti et. al. (2015)

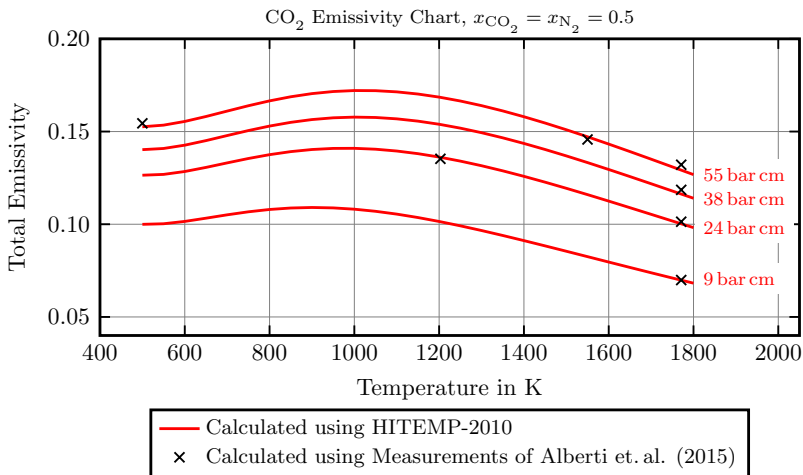
H_2O and CO_2 at 1770 K, $x_{\text{H}_2\text{O}} = x_{\text{CO}_2} = 0.43$, $P_t = 1 \text{ atm}$, $L = 54 \text{ cm}$



$$\text{Difference} = \tau_{\eta,\text{Measured}} - \tau_{\eta,\text{HITEMP-2010}}$$

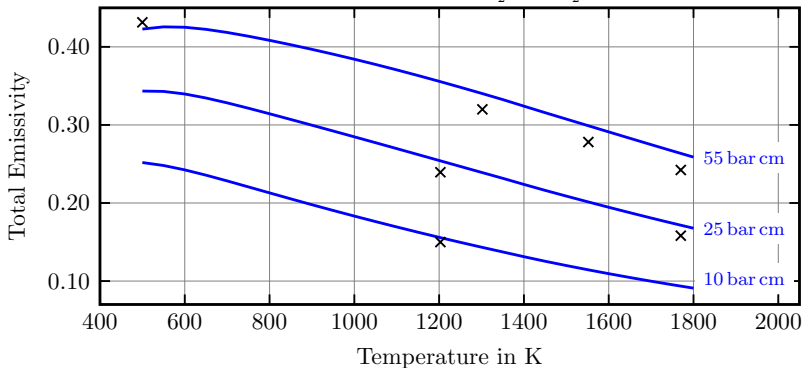
see Alberti et. al. [3]

High Temperature - Alberti et. al. (2015)



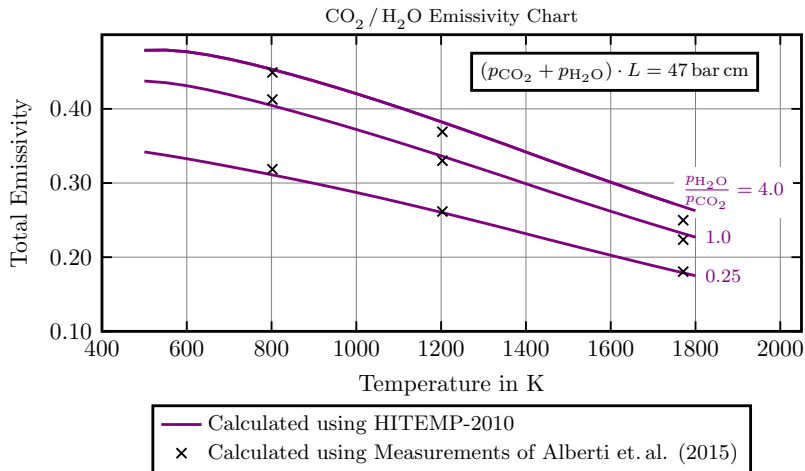
High Temperature - Alberti et. al. (2015)

H_2O Emissivity Chart, $x_{\text{H}_2\text{O}} = x_{\text{N}_2} = 0.5$



— Calculated using HITEMP-2010
 × Calculated using Measurements of Alberti et. al. (2015)

High Temperature - Alberti et. al. (2015)



$$pL = (p_{\text{CO}_2} + p_{\text{H}_2\text{O}}) \cdot L$$



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High Pressure

Important Results for CO₂ (without any claim to completeness)

■ Measurements

- Fukabori et. al. (1986) [7]
- Hartmann and Perrin (1989) [8, 12]
- Scutaru et. al. (1993) [13]

■ Models / Adjustments

- Full Line-Mixing software of Lamouroux [10]
- χ -factors of Tran (2011) [14]
- Cut-off criterion of Alberti et. al. (2015) [2]
 - Number Lorentz-half-widths

$$n(T, P_t) = 4.0 \cdot \left(\frac{T}{P_t} \right)^{0.822}$$

High Pressure

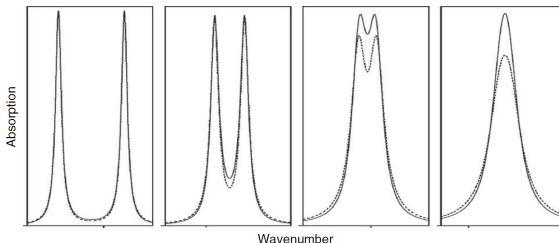
Important Results for CO₂ (without any claim to completeness)

■ Measurements

- Fukabori et. al. (1986) [7]
- Hartmann and Perrin (1989) [8, 12]
- Scutaru et. al. (1993) [13]

■ Models / Adjustments

Line-Mixing (finite duration of collision)



Taken from Hartmann [9]

High Pressure

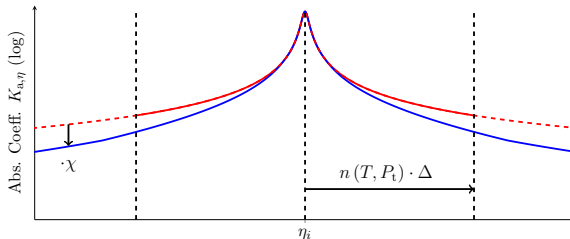
Important Results for CO₂ (without any claim to completeness)

■ Measurements

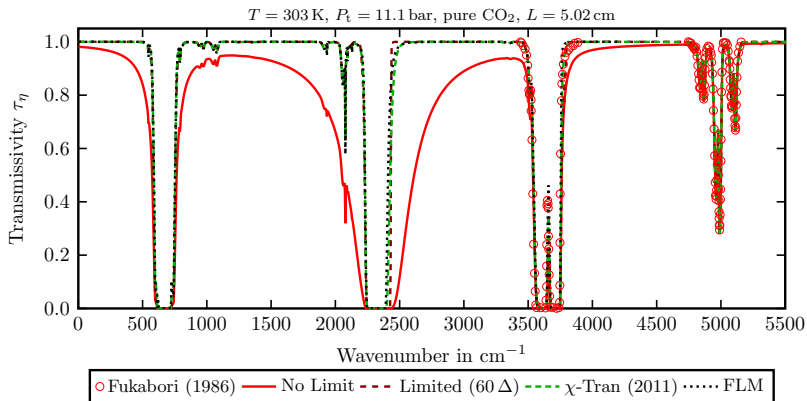
- Fukabori et. al. (1986) [7]
- Hartmann and Perrin (1989) [8, 12]
- Scutaru et. al. (1993) [13]

■ Models / Adjustments

Adjustments for Lorentz / Voigt Lineshape

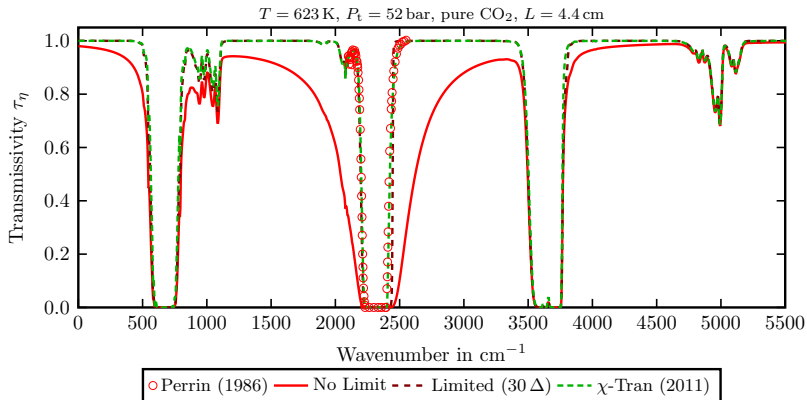


High Pressure - Alberti et. al. (2015)



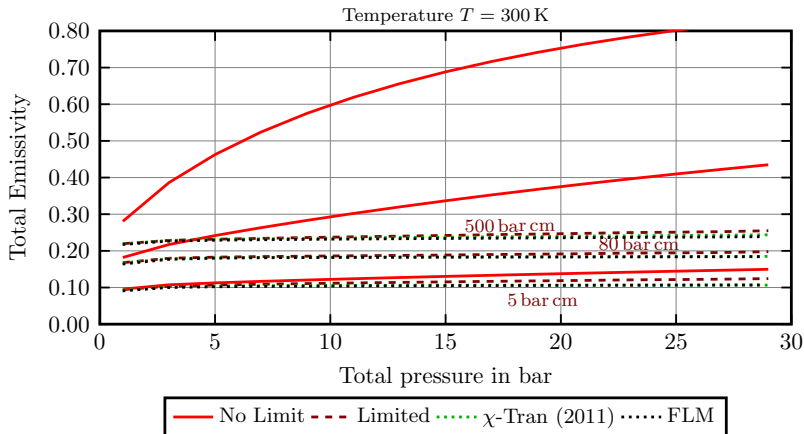
see also Ref. [2]

High Pressure - Alberti et. al. (2015)



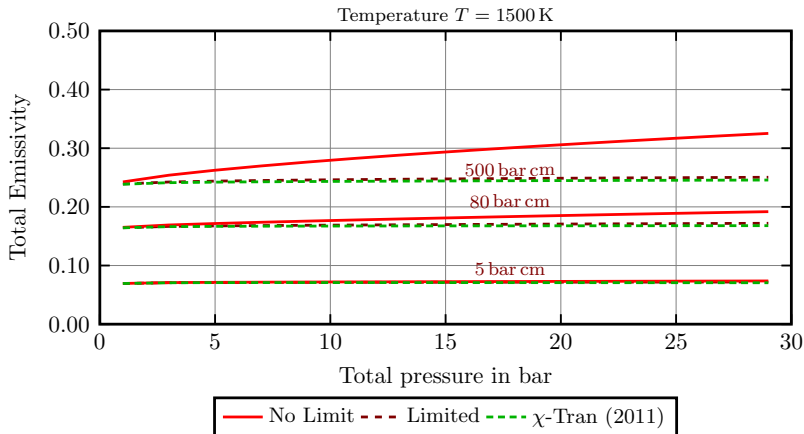
see also Ref. [2]

High Pressure - Alberti et. al. (2015)



see also Ref. [2]

High Pressure - Alberti et. al. (2015)



see also Ref. [2]



Content of this Chapter

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Summary and Conclusion

- High temperature and atmospheric pressures
 - CO_2 : maximum 2 % difference (up to 1770 K)
 - H_2O : maximum 9 % difference (up to 1770 K)
 - $\text{CO}_2 + \text{H}_2\text{O}$: maximum 7 % difference (up to 1770 K)
- High pressure / density
 - Measurements for small spectral regions
 - New, full spectrum measurements are needed
 - Lineshape adjustment seems to be essential
- CO measurements for gasification applications



Acknowledgments

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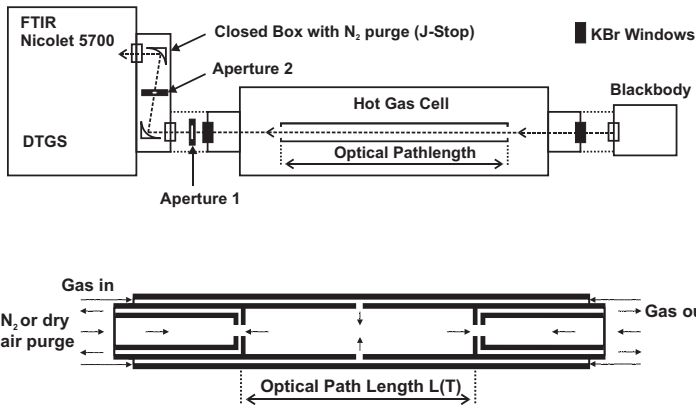
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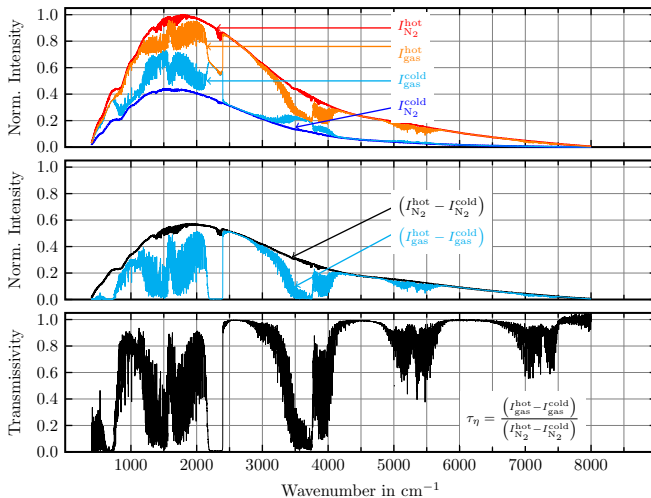
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Appendix

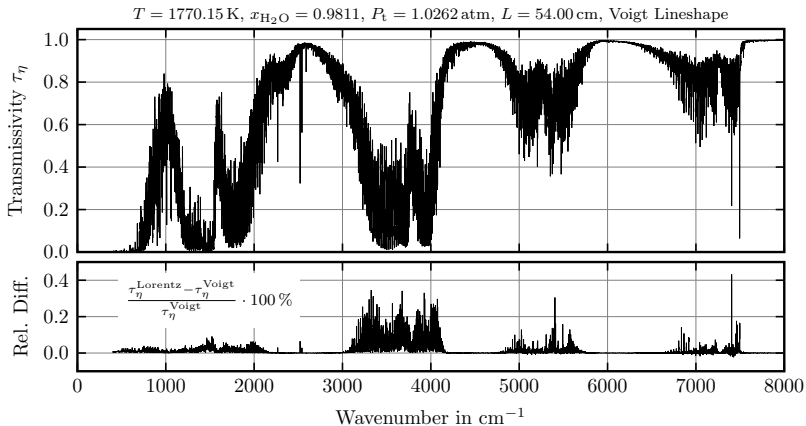


The gas cell design can be traced back to Hottel & Mangelsdorf (1935). [3]

Appendix



Appendix



See also Ref. [3]